

Pedal Anomalies in *Neobisium carpaticum* BEIER
and *Roncus pannoni* ČURČIĆ, DIMITRIJEVIĆ et
KARAMATA (Pseudoscorpiones: Neobisiidae)
from Yugoslavia

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Abstract Anomalies in the pedal segmentation patterns were studied in *Neobisium carpaticum* BEIER and *Roncus pannoni* ČURČIĆ, DIMITRIJEVIĆ et KARAMATA (Neobisiidae), inhabiting Yugoslavia. A total of 10 abnormal examples were found out of 7,280 specimens examined. The frequency of the aberrant specimens was variable, depending on the growth stage, sex, and species. In *N. carpaticum*, the following malformations were noted: partial atrophy, atrophy, and symphysopody; and combinations of different deficiencies [combined atrophy and symphysopody; combined partial division and partial symphysopody; and combined partial atrophy, symphysopody, and schistomely (or heteromorphosis)]. In *R. pannoni*, however, only symphysopody as well as two combined anomalies (multiple atrophy; and combined atrophy and symphysopody) were found. Teratological variation of the pedal podomeres has been confined only to adults. Additionally, some specific features of the relative distribution of various pedal anomalies are considered. Finally, the probable causes of the origin and development of pedal anomalies in the pseudoscorpions studied have been also discussed.

Introduction

Developmental anomalies are known to occur in pseudoscorpions, the most common being the malformations of various abdominal sclerites (ČURČIĆ *et al.*, 1991). However, records of the aberrations of the walking legs are rare and consist of brief reports by MAHNERT (1973), ČURČIĆ (1980, 1985, 1988), ČURČIĆ *et al.* (1993, 1994a, 1994b), and JUDSON (1993), who provide different examples in European and Asian pseudoscorpions, respectively. More recently, ČURČIĆ *et al.* (in preparation) have provided further examples and attempted to quantify the phenomenon.

In the species studied, the deformities of the walking legs were confined to the tritonymph/adult, or transformation molt. Although aberrations in pseudoscorpions were thought to represent post-embryonic molt phenomena (PEDDER, 1965), their origin and development are still not sufficiently understood.

Among the Cheliferinea, pedal malformations have been described in *Chelifer cancrivorus* (LINNAEUS), *Ellingsenius fulleri* (HEWITT et GODFREY), and *Diplotrixochernes patagonicus* BEIER (VACHON, 1947; BEIER, 1962; JUDSON, 1990). In the

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Chthoniinea, no aberrations of walking legs have been noted so far (ČURČIĆ *et al.*, in prep.). Among the Neobisiinea, false scorpions have been found with different pedal deficiencies. Such aberrations have been noted in *Bisetocreagris gracilis* (REDIKORZEV), *B. japonica* (ELLINGSEN), *B. ussuriensis* (REDIKORZEV), *Neobisium sylvaticum* (C. L. KOCH), *N. aff. tantaleum* BEIER, *Roncus ciobanmos* ČURČIĆ, POINAR *et SARBU*, *R. parablothroides* HADŽI, and *R. giganteus* MAHNERT (MAHNERT, 1973; ČURČIĆ, 1980, 1985, 1988; ČURČIĆ *et al.*, 1993, 1994a, 1994b, in prep.; JUDSON, 1993).

Quantitative and qualitative analysis of the samples of different neobisiid species revealed a number of aberrations in the walking legs. Thus, in *B. gracilis*, from Kazakhstan (former USSR), the right telofemur IV has an additional constriction (incomplete joint; ČURČIĆ, 1985). Furthermore, ČURČIĆ *et al.* (1994a) noted an anomaly of the right leg IV in *B. japonica* from Japan; the size of the abnormal articles is smaller than usual, which causes the length/breadth ratios of different podomeres differ from those of the normal (left) leg IV. Additionally, an enlarged pretarsus with two tiny claws and two setae (usually none!) is developed distally on the abnormal leg. As a consequence, the setal counts and disposition have been drastically changed (ČURČIĆ *et al.*, 1994a). Pedal anomaly in *B. ussuriensis* from the Russian Far East was manifested in the size and setation of the right telotarsus IV; it was assumed that the malformation present is due to the presence of the (? mermithid) nematode parasite, found in the abdomen of the anomalous specimen (JUDSON, 1993).

One of the most unusual symmetrical abnormalities yet found in pseudoscorpions was noted in *N. sylvaticum* from Yugoslavia (ČURČIĆ, 1980). On both third and fourth legs, the basitarsi are narrower and more elongate in relation to normal specimens (ČURČIĆ, 1982). On the other hand, telotarsi III and IV are thicker and relatively shorter than usual. Furthermore, in *R. ciobanmos* from Romania an anomalous right telotarsus IV, carrying 2 long sensitive setae (instead of 1) has been recorded by ČURČIĆ *et al.* (1993). A similar case of pedal malformation has been noted in *R. parablothroides* from Turkey, with the left telotarsus IV bearing 2 sensitive setae (instead of 1) (ČURČIĆ *et al.*, 1994b). Additionally, MAHNERT (1973) reported on a malformation in *R. giganteus* from Greece, with the fused left basitarsus and telotarsus I (and with triple claw pairs and arolia).

The primary purpose of this study was to analyze the quantitative and qualitative variation of pedal deficiencies in two sympatric species, *Neobisium carpaticum* BEIER, and *Roncus pannoniensis* ČURČIĆ, DIMITRIJEVIĆ *et* KARAMATA, their frequencies, common occurrences, and the possible factors affecting their development and distribution.

Material and Methods

We have analyzed the teratological variation of pedal deficiencies in the population samples of *N. carpaticum* and *R. pannoniensis*, both from the village of Obrež, near Belgrade, Yugoslavia. The numbers of specimens of each species, collected in this locality are presented in Table 1.

Samples of the two pseudoscorpion species were obtained by sifting oak leaf litter and humus over a period from March 1991 to September 1992. Samples were

Table 1. The number of specimens of *Neobisium carpaticum* BEIER and *Roncus pannoniensis* ČURČIĆ, DIMITRIJEVIĆ et KARAMATA (by sex and growth stages), from Yugoslavia. F=Females, M=males, T=tritonymphs, D=deutonymphs, P=protonymphs.

Species	Sex/instar					Total
	F	M	T	D	P	
<i>N. carpaticum</i>	1,121	1,529	693	233	218	3,794
<i>R. pannoniensis</i>	1,209	1,600	633	43	1	3,486

Table 2. Pedal abnormalities in different sexes and growth stages of *Neobisium carpaticum* BEIER and *Roncus pannoniensis* ČURČIĆ, DIMITRIJEVIĆ et KARAMATA, from Yugoslavia. F=Females, M=males, T=tritonymphs, D=deutonymphs, P=protonymphs.

Species	Sex/instar					Total	% abnormal males	% abnormal specimens
	F	M	T	D	P			
<i>N. carpaticum</i>	3	3	—	—	—	6	50	0.16
<i>R. pannoniensis</i>	2	2	—	—	—	4	50	0.11

taken once a month. After dissection, all specimens were mounted in gum chloral medium (Swan's fluid) and examined carefully. The terminology for pedal anomalies in this study is the same as used for other arthropods (BALAZUC, 1948). This terminology has been somewhat modified in the present paper to include the whole range of pedal malformations which were observed in pseudoscorpions.

Results

There was a total of 10 abnormal specimens (6 of *N. carpaticum* and 4 of *R. pannoniensis*; Table 2). Analysis of teratological variation of pedal anomalies in the pseudoscorpions studied gave the following results:

Neobisium carpaticum

Female (Figs. 1, 2). The right tibia IV and basitarsus IV are anomalous; the former podomere has an additional, incomplete joint distally. Furthermore, the abnormal tibia IV and basitarsus IV are fused partially at the tibio-basitarsal joint (Fig. 2). As a consequence, the form of tibia IV and basitarsus IV is changed (Figs. 1, 2); additionally, the anomalous (right) tibia IV is longer than the normal (left) one ($0.62\text{ mm} + 0.305\text{ mm} = 0.925\text{ mm}$ vs. 0.79 mm) and its length to breadth ratio is higher than in the normal tibia IV (5.78 vs. 5.27 ; see also ČURČIĆ, 1982). The left leg IV is normal (Fig. 1). **Partial division** (tibia IV) and **partial symphysopody** (tibia IV and basitarsus IV).

Female (Figs. 3, 4). In this specimen, the abnormal left telotarsus IV is somewhat shorter than its complement on the right (0.38 mm vs. 0.44 mm). Consequent-

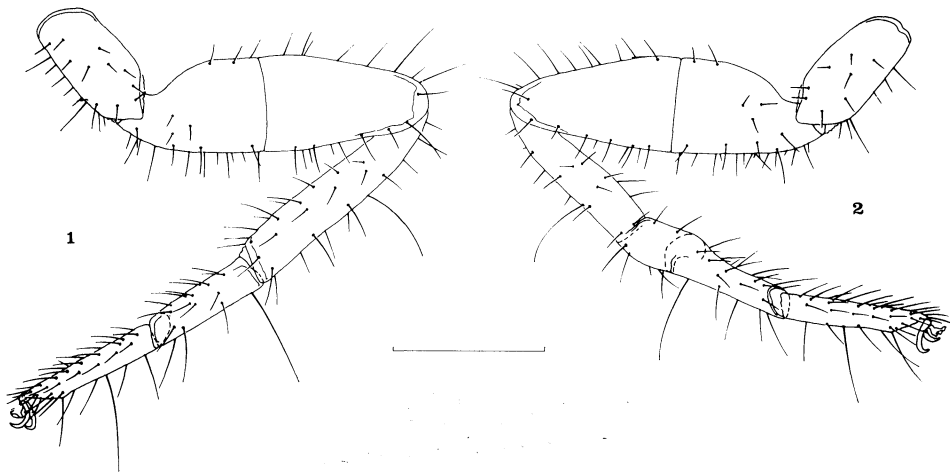


Fig. 1–2. *Neobisium carpaticum* BEIER, female from Yugoslavia. —1, Left (normal) leg IV; 2, right (abnormal) leg IV. Scale line = 0.5 mm.

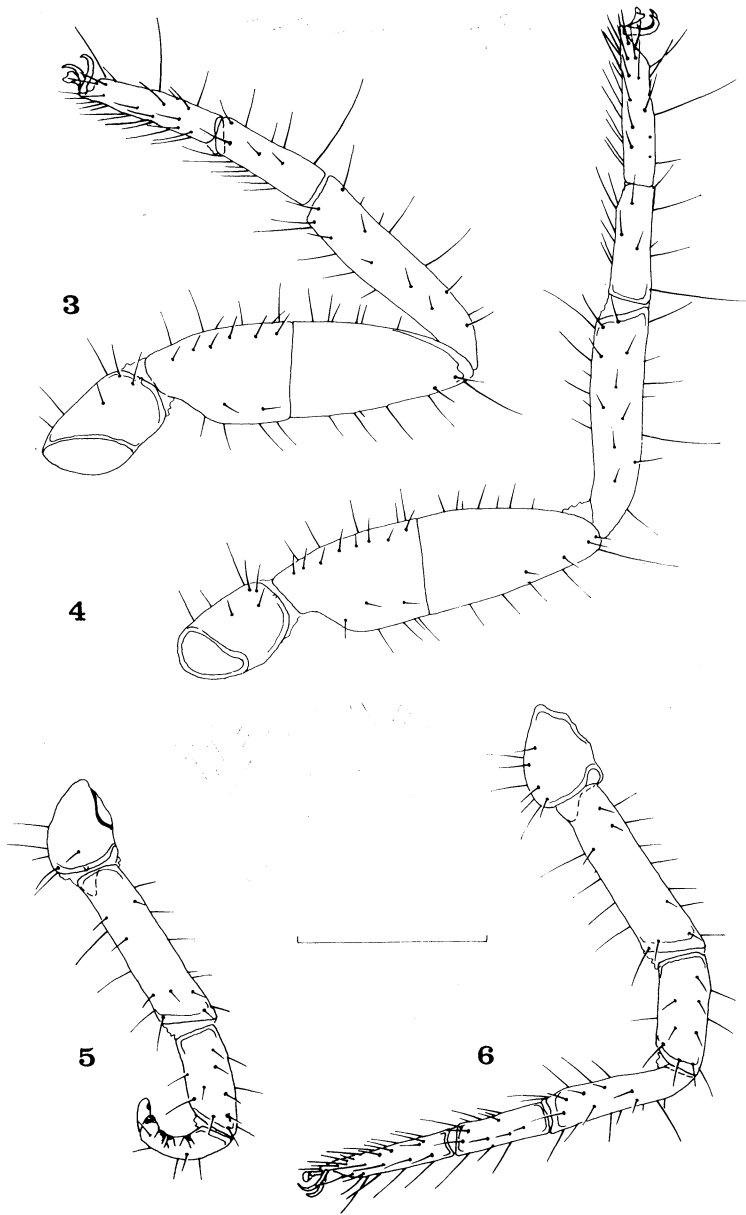
ly, the tip of the anomalous podomere is somewhat blunt; and the ratio of the left (abnormal) telotarsus IV length to breadth is somewhat lower than in the right (normal) telotarsus IV (4.75 vs. 5.50). The right leg IV is normal in all respects (Fig. 4). **Partial atrophy** (telotarsus IV).

Female (Figs. 5, 6). The left (anomalous) leg II lacks tibia, basitarsus, and telotarsus (Fig. 5); instead, a two-segmented, worm-like structure is developed. This appendix consists of a small and wrinkled podomere proximally (probably representing either a part of tibia II, or of reduced tibia II and basitarsus II), and of a minute apical segment distally (with no setae, claws, and arolium present). This distalmost podomere probably represents either a reduced basitarsus II (with telotarsus II lacking), or a rudiment of fused basitarsus II and telotarsus II). As a consequence of this complex anomaly, the form and size of the left (aberrant) leg II have been drastically changed if compared to the right (normal) leg II (Figs. 5, 6). **Atrophy** (tibia II, basitarsus II, and telotarsus II) and **symphysopody**.

Male (Figs. 7, 8). The left leg II is anomalous; its basitarsus and telotarsus have been fused into a single podomere. This fused article is deprived of setae proximally. The right leg is apparently normal (Fig. 8). **Symphysopody** (basitarsus II and telotarsus II).

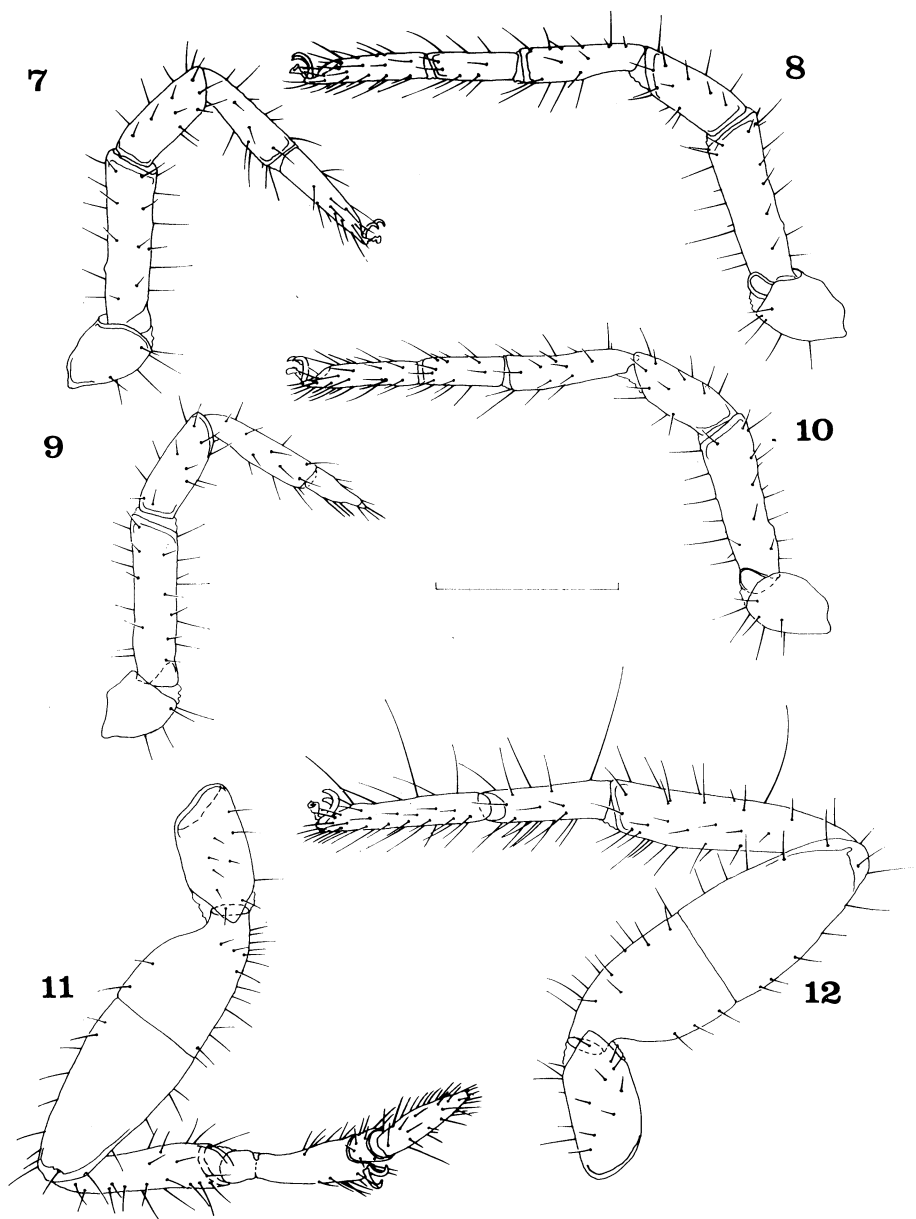
Male (Figs. 9, 10). In this specimen, the left basitarsus II is conical and reaches as much as 78% the length of its normal (right) complement. Distal to the anomalous basitarsus II, a bisetous tiny rudiment (representing probably a part of the missing telotarsus II) has been developed (Fig. 9). As a consequence, the setation of the two anomalous podomeres has been drastically changed in comparison to normal specimens (Fig. 10; ČURČIĆ, 1982). The right leg II is normal in all respects (Fig. 10). **Atrophy** (basitarsus II and telotarsus II).

Male (Figs. 11, 12). In this example, striking aberration of the left leg IV affects the podomeres distal to femur IV. The anomalous (left) tibia IV is shorter



Figs. 3–6. *Neobisium carpaticum* BEIER, females from Yugoslavia. —3, Left (abnormal) leg IV; 4, right (normal) leg IV; 5, left (abnormal) leg II; 6, right (normal) leg II. Scale line=0.5 mm.

than its normal (right) complement (0.51 mm vs. 0.68 mm). The following article (? basitarsus IV+telotarsus IV) has been partially divided into two sections of unequal form and size (Fig. 11): the proximal part of this podomere is deprived of



Figs. 7-12. *Neobisium carpaticum* BEIER, males from Yugoslavia. —7, Left (abnormal) leg II; 8, right (normal) leg II; 9, left (abnormal) leg II; 10, right (normal) leg II; 11, left (abnormal) leg IV; 12, right (normal) leg IV. Scale line=0.5 mm.

setae; its distal part carries, apically and laterally, a pair of claws. Furthermore, this podomere carries two supernumerary podomeres of unequal form and size

apically (Fig. 11). These two podomeres are developed instead of a pretarsus IV, and probably represent a case of schistomely or heteromorphosis. As a consequence, the form, size, and setation of the anomalous podomeres (with no tactile setae!) are drastically changed in relation to their normal complements (Figs. 11, 12). The right leg IV is otherwise normal (Fig. 12). **Partial atrophy** (tibia IV), **symphysopody** (basitarsus IV and telotarsus IV), and **schistomely** (or **heteromorphosis**).

Roncus pannoni

Female (Figs. 13, 14). The left basitarsus III and telotarsus III have fused into a short and stunt podomere, bearing a single sensitive seta (instead of 2), and a single claw (instead of 2) (Fig. 13). The right leg III is normal in all respects (Fig. 14). **Atrophy** and **symphysopody** (basitarsus III and telotarsus III).

Female (Figs. 15, 16). The left tibia IV is followed only by a single small podomere; hence, the left basitarsus IV and telotarsus IV are not fully developed (Fig. 15). Consequently, the anomalous podomere represents either a part of the left basitarsus IV (with left telotarsus IV missing), or the fusion of parts of the left basitarsus IV and telotarsus IV; in addition, this small aberrant podomere is deprived of sensitive setae (Fig. 15). The right leg IV is normal (Fig. 16). **Atrophy** and (?) **symphysopody** (basitarsus IV and telotarsus IV).

Male (Figs. 17, 18). In this specimen, the left tibia III is greatly reduced if compared to its right (normal) complement (0.24 mm vs. 0.47 mm); it also lacks a sensitive seta. Additionally, the anomalous leg lacks both basitarsus III and telotarsus III (Fig. 17). The right leg III is normal (Fig. 18). **Multiple atrophy** (tibia III, basitarsus III, and telotarsus III).

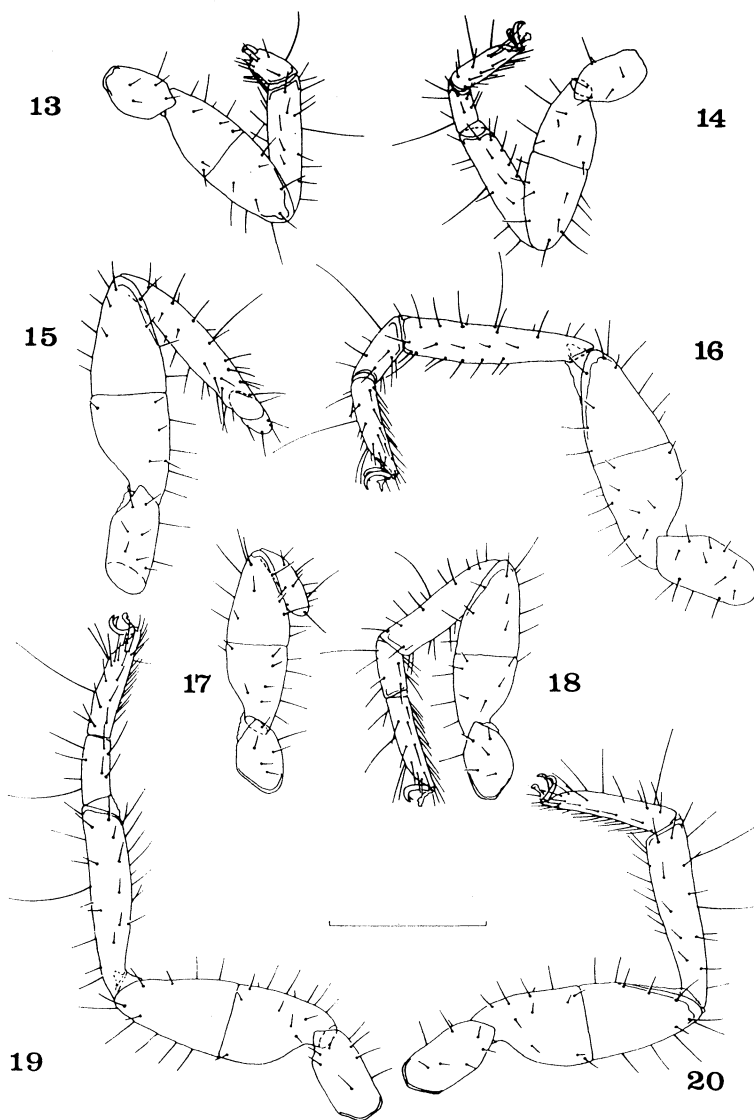
Male (Figs. 19, 20). The right basitarsus IV and telotarsus IV are fused into a single podomere, carrying a single tactile seta (instead of 2; Fig. 19). The left basitarsus IV and telotarsus IV are normal in all respects (Fig. 20). **Symphysopody** (basitarsus IV and telotarsus IV).

The percentages of anomalies of males and females of *N. carpaticum* and *R. pannoni* were identical for any of the two species (Table 2). Thus these data offer no confirmation that a sex-linked inheritance of pedal malformations exists in the analyzed species. Since all anomalous pseudoscorpions were adults (Table 2), it is supposed that at least some pedal malformations may arise through the transformation (molt) process, just as is the case with some abdominal anomalies (ĆURČIĆ *et al.*, 1991). However, the structural complexity of some other pedal aberrations supports the assumption that these malformations arise during early ontogeny.

Discussion

All postembryonic instars of each species were found in the locality studied; however, the number of protonymphs of *R. pannoni* was exceedingly low, particularly if compared to the number of other developmental stages of the species, or to the protonymphs of *N. carpaticum* (Table 1).

In the more frequently species, *N. carpaticum*, 6 abnormal specimens were noted, whereas in *R. pannoni* the number of aberrant examples was 4. All abnormal specimens were adults (Table 2).



Figs. 13–20. *Roncus pannoniensis* ČURČIĆ, DIMITRIJEVIĆ et KARAMATA, from Yugoslavia.—— 13, Left (abnormal) leg III, female; 14, right (normal) leg III, female; 15, left (abnormal) leg IV, female; 16, right (normal) leg IV, female; 17, left (abnormal) leg III, male; 18, right (normal) leg IV, male; 19, left (normal) leg IV, male; 20, right (abnormal) leg IV, male. Scale line=0.5 mm.

In *N. carpaticum* we found that the frequency of pedal malformations is 0.16%, whereas in *R. pannoniensis* it is 0.11% (Table 2). In general, these values are much lower than the frequency of abdominal anomalies in the two species (ČURČIĆ, 1989a,

1989b; ČURČIĆ & DIMITRIJEVIĆ, 1988; ČURČIĆ *et al.*, 1991). It is also pertinent to note that the frequency of pedal anomalies is essentially similar in both analyzed species (Table 2).

The deficiencies in pedal structures of the two species were variable. Thus in *N. carpaticum* as many as six types of single or combined anomalies were noted. Among single anomalies, one should mention: partial atrophy (Fig. 3), atrophy (Fig. 9), and symphysopody (Fig. 7); combined anomalies in this species were restricted to atrophy and symphysopody (Fig. 5), partial division and partial symphysopody (Fig. 2), and to partial atrophy, symphysopody, and schistomely (Fig. 11). However, in *R. pannoniensis* only one type of single anomaly was found (symphysopody; Fig. 20), whereas combined anomalies include: multiple atrophy (Fig. 17), and atrophy and symphysopody (Figs. 13 & 15). It is noteworthy that both atrophy and symphysopody have been found the most frequent malformations in both analyzed species (66.7% in *N. carpaticum*, and 75.0% in *R. pannoniensis*).

The sex-linked distribution of pedal anomalies varies considerably depending on the sample (or species) studied. Thus in *N. carpaticum* 0.27% of females and 0.20% of males were aberrant. In *R. pannoniensis* the teratological incidence varied from 0.165% (females) to as low as 0.125% (males; see also Table 2). In each analyzed species, pedal deficiencies were unequally distributed among representatives of different sexes, *i.e.* the percentage of anomalous females was higher than that of aberrant males.

The study of the relative distribution of pedal malformations in the adult stage of *N. carpaticum* and *R. pannoniensis* (Figs. 1–20; Tables 1 & 2) revealed the following: 1) in both species, the first pair of walking legs is deprived of any structural anomalies; 2) the third pair (*N. carpaticum*) or the second pair of walking legs (*R. pannoniensis*) also lack any malformations; 3) in the majority of examples (5 specimens or 83.3% in *N. carpaticum*, and 3 specimens or 75.0% in *R. pannoniensis*), anomalies affect pedal podomeres on the left side; 4) in both analyzed species, the proximal podomeres of all walking legs (coxa, trochanter, femur I, and femur II) were not affected by any structural deformity; and, 5) pedal anomalies affect the tibiae, and especially the basitarsi and telotarsi of the legs II and IV (*N. carpaticum*), as well as of the legs III and IV (*R. pannoniensis*), respectively.

In the majority of cases, the development of pedal malformations causes simultaneous aberrations in the form, size, and setation of different podomeres, as well as in the presence or absence of sensitive setae, tarsal claws, and arolia. In other words, changes in the number, size, and disposition of different pedal structures result from deficiencies affecting either parts of or whole podomeres.

A number of segmental (and pedal) anomalies are likely to be result of earlier mechanical, physical, or chemical injury; additionally, the malfunction of the hormonal system, as well as the environmental factors may also spark the origin of some pedal malformations (ČURČIĆ *et al.*, 1991). However, it seems probable that the genetic factors can also give rise to such aberrations (GILBERT, 1988). There are a number of findings which would support this view: the constancy of teratological variation in wild populations, a comparatively similar incidence in percentage of abnormal specimens in different species, the noted degree of qualitative diversity and specific features of the distribution of different aberrations in both sexes in each particular species (ČURČIĆ *et al.*, 1991).

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